

CO₂ TRANSPORT – BUILDING ON THE CURRENT FRAMEWORK TO MEET THE DEMANDS OF WIDELY DEPLOYED, COMMERCIAL SCALE CCS SYSTEMS

SIXTH ANNUAL CONFERENCE ON
CARBON CAPTURE & SEQUESTRATION
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L. Stephen Melzer
Melzer CO₂ Consulting
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CO₂ TRANSPORT FOR COMMERCIAL SCALE CCS SYSTEMS

- 1) The Evolving Framework for CO₂ Pipeline Systems
- 2) Pipeline CO₂ Specifications
- 3) Existing Transportation (Pipeline) Models
- 4) The Future Challenge – Examples of Networks
- 5) Point-to-Point, Ownership and Open Access Issues
- 6) Facilitating the Pipelines – Government/Quasi Government and Commercial Facilitators

SPECIAL ACKNOWLEDGEMENTS

- The Interstate Oil & Gas Compact Commission's Subcommittee on Carbon Capture and Sequestration (specifically the IOGCC and the Contributing Regulator Members)
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- The Technology and Best Practices Sharing of the Oil and Gas Industry

THE EVOLVING FRAMEWORK for CO₂ Pipeline Systems

- Type I** Special, Single Use Pipelines
(Case-by-case Specifications for
Carried Fluid Composition)
- Type II** The North American Network i.e.,
Multiple Source and User Lines
(Strict Specified CO₂ Composition)
- Type III** Hybrid Lines (Relaxed but
Controlled CO₂ Composition)

TYPE I

SPECIAL, SINGLE USE “CO₂” PIPELINES

- Does Not Attempt to Commoditize CO₂
- Minimizes Processing Cost of CO₂
- Specification of Carrier (Injectate) Fluid Could Vary Widely
- Would Most Often be a Short Run Pipeline Connecting Single Source to Single Sinks or Sink Clusters
- Common Source-to-Sink Ownership

No Current (High Volume) Operational Models for Type I CO₂ Pipelines

Current CO₂ Pipeline Systems

(Emphasized Herein)
i.e., Commodity CO₂ Lines

Types II and III

Type II

MULTIPLE SOURCE AND USER LINES (HIGH VALUE AND SPECIFIED CO₂ COMPOSITION)

- Designed to Connect Multiple Sources with Multiple Sinks
- Strict Specifications for CO₂
- Multiple Pipeline Interconnects
- Several Pipeline Models Exist Today that can/will Interconnect to Future Lines (Perhaps Evolving to a North American CO₂ Pipeline Network)

Type III HYBRID CO₂ PIPELINES

- Can Include Multiple Sources and Multiple Sinks
- Locally Sink-Defined Specifications for CO₂
- Commodity Pipeline (Lower Value Carrier Fluid)
 - e.g., High H₂S, High N₂ (ECBM)
- Shorter Run Pipelines
- Possible Special Operational Safety Issues
 - e.g., High H₂S Concentrations

EXISTING TRANSPORTATION MODELS

PIPELINE	Owner/Operator	Length (mi)	Length (km)	Diameter - in	Estimated Max Flow	Estimated Max Flow	Location	PL Type
					Capacity (mmcfpd)	Capacity (million tons/yr)		
Adair	Apache	15	24	4	47	1.0	TX	II
Anadarko Powder River Basin CO2 PL	Anadarko	125	201	16	204	4.3	WY	II
Anton Irish	Oxy	40	64	8	77	1.6	TX	II
Bravo	Oxy Permian	218	351	20	331	7.0	NM, TX	II
Canyon Reef Carriers	Kinder Morgan	139	224	16	204	4.3	TX	II
Centerline	Kinder Morgan	113	182	16	204	4.3	TX	II
Central Basin	Kinder Morgan	143	230	16	204	4.3	TX	II
Chaparral	Chaparral Energy	23	37	6	60	1.3	OK	II
Choctaw	Denbury Resources	183	294	20	331	7.0	MS, LA	II
Comanche Creek (2007 reactivated)	PetroSource	100	161	6	60	1.3	TX	II
Cordona Lake	XTO	7	11	6	60	1.3	TX	II
Cortez	Kinder Morgan	502	808	30	1117	23.6	TX	II
Dollarhide	Chevron	23	37	8	77	1.6	TX	II
El Mar	Kinder Morgan	35	56	6	60	1.3	TX	II
Enid-Purdy (Central Oklahoma)	Anadarko	117	188	8	77	1.6	OK	II
Este I - to Welch, Tx	ExxonMobil, et al	40	64	14	160	3.4	TX	II
Este II - to Salt Crk Field	ExxonMobil	45	72	12	125	2.6	TX	II
Ford	Kinder Morgan	12	19	4	47	1.0	TX	II
Joffre Viking	Penn West Petroleum Ltd.	8	13	6	60	1.3	Alberta	II
Llano	Trinity CO2	53	85	12-8	77	1.6	NM	II
Pecos County	Kinder Morgan	26	42	8	77	1.6	TX	II
Raven Ridge	Chevron	160	257	16	204	4.3	WY/Co	II
Sheep Mtn	British Petroleum	408	656	24	538	11.4	TX	II
Shute Creek	ExxonMobil	30	48	30	1117	23.6	WY	II
Slaughter	Oxy Permian	35	56	12	125	2.6	TX	II
Transpetco	TransPetco	110	177	8	77	1.6	TX, OK	II
W. Texas	Trinity CO2	60	97	12-8	77	1.6	TX, NM	II
Wellman	PetroSource	25	40	6	60	1.3	TX	II
White Frost	Core Energy, LLC	11	18	6	60	1.3	MI	II
Wyoming CO2	ExxonMobil	112	180	20-16	204	4.3	WY	II
Dakota Gasification (Souris Valley)	Dakota Gasification	204	328	16	204	4.3	ND/Sask	III
Pikes Peak	PetroSource	40	64	8	77	1.6	TX	III
Val Verde	PetroSource	83	134	10	98	2.1	TX	III

* Tabulation does not include many shorter high pressure trunk lines to individual fields

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CO₂ PIPELINE SPECIFICATIONS

EXAMPLE 1 (Type II)

NATURAL SOURCE (COMPANY "X") Permian Basin CO₂ Specifications

Gas specifications

CO ₂	95%	by volume
H ₂ S	<10	ppmbw
Sulphur	<35	ppmbw
Total Hydrocarbons	<5%	by volume
CH ₄	-	not specified
C ₂ + hydrocarbons	-	not specified
CO	-	not specified
N ₂	<4%	by volume
O ₂	<10	ppmbw
H ₂ O	<25	#/mmcf

* Personal Communications

CO₂ PIPELINE SPECIFICATIONS

EXAMPLE 2 (Type II)

NATURAL SOURCE (COMPANY "Y") Permian Basin CO₂ Specifications*

Gas specifications

CO ₂	95% by volume
H ₂ S	<20 ppm bw
Sulphur	<30 ppm bw
Total Hydrocarbons	<5% mole %
CH ₄	- not specified
C ₂ + hydrocarbons	- not specified
CO	- not specified
N ₂	<4% mole %
O ₂	<10 ppm bw
H ₂ O	<30 #/mmcf

* Personal Communications

CO₂ PIPELINE SPECIFICATIONS

EXAMPLE 3 (Type III)

Dakota Gasification Corporation WEYBURN PIPELINE

Gas specifications

CO ₂	96% by volume
H ₂ S	0.90%
Sulphur	-
Total Hydrocarbons	-
CH ₄	0.70%
C ₂ + hydrocarbons	2.30%
CO	0.10%
N ₂	<300 ppmbv
O ₂	<50 ppmbv
H ₂ O	<20 ppmbv

* Ref: <http://www.apgtf-uk.com/15Jan03/pdf/09%20RILEY%20Transport%2015Jan03.pdf>

SUMMARY OF CO₂ PIPELINE SPECIFICATIONS

Parameter	II	II	III
Parameter	Example 1	Example 2	Example 3
CO ₂ - % by volume	95%	95%	96%
H ₂ S - ppmbw	10	20	10,000
Sulphur - ppmbw	35	30	-
Total Hydrocarbons - % by volume	5	5	-
CH ₄ - % by volume	-	-	700
C ₂ + hydrocarbons - % by volume	-	-	23,000
CO - % by volume	-	-	1,000
N ₂ - % by volume/wt	4	4	300
O ₂ - ppm by wt/vol	10	10	50
H ₂ O - #/mmcf* or ppm by vol	25*	30*	20

CONTAMINANT ISSUES

Affecting CO₂ Commodity Value

Pipeline Corrosion (Water and Oxygen)

Safety (e.g., H₂S)

Dense (Critical) Phase Degradation

Reservoir Microbial Activity (e.g., Oxygen)

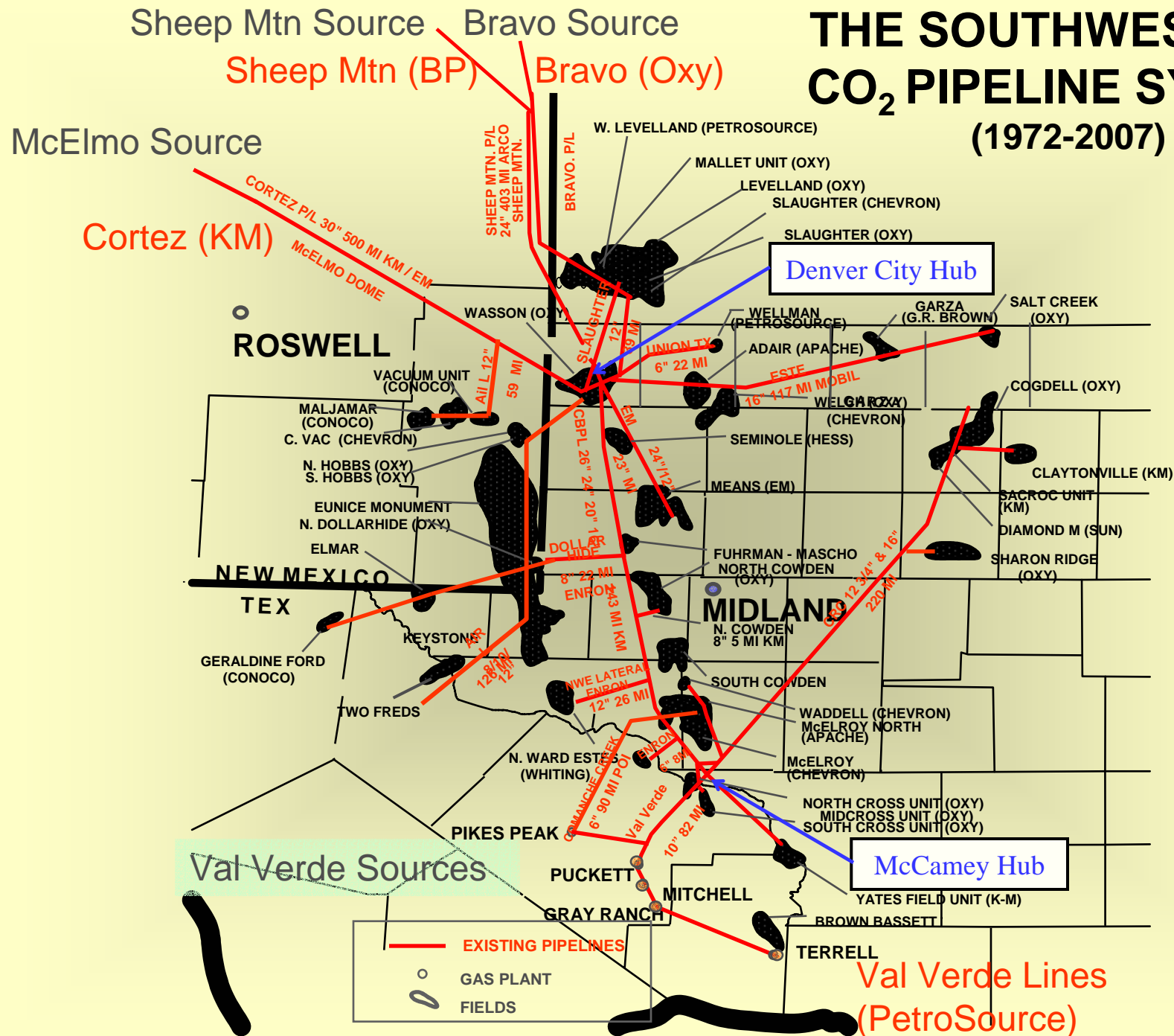
Oil Miscibility (Methane and Nitrogen)

Enhanced Gas Recovery

Others?

EXAMPLE NETWORKS (EXISTING)

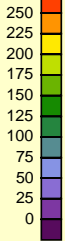
THE SOUTHWEST U.S. CO₂ PIPELINE SYSTEM (1972-2007)





1986 to 2000

Legend
OOIP, MMBO



Idaho

Montana

South Dakota

Exxon La Barge
CO₂ Source Field

Lost Soldier, Wertz
CO₂ Flood

Wyoming

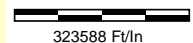
**THE WYOMING & W. COLORADO
CO₂ PIPELINE SYSTEM
(1986-2000)**

Utah

Rangely Unit
CO₂ Flood

Colorado

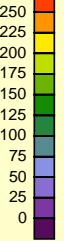
*After Petty (2004 CO₂
Conference)*





Period
2001

Legend
OOIP, MMBO



Idaho

Montana

South Dakota

La Barge
CO₂ Source Field

Hartzog Draw

Salt Creek

Lost Soldier, Wertz
CO₂ Flood

Wyoming

**THE WYOMING & W. COLORADO
CO₂ PIPELINE SYSTEM
(1986-2001)**

Utah

Rangely Unit
CO₂ Flood

Colorado

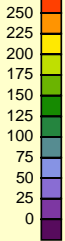
*After Petty (2004 CO₂
Conference)*

323588 Ft/in



Period
2001 on

Legend
OOIP, MMBO



Idaho

Montana

South Dakota

La Barge
CO₂ Source Field

Salt Creek

Lost Soldier, Wertz
CO₂ Flood

Wyoming

**THE WYOMING & W. COLORADO
CO₂ PIPELINE SYSTEM
(1986-?)**

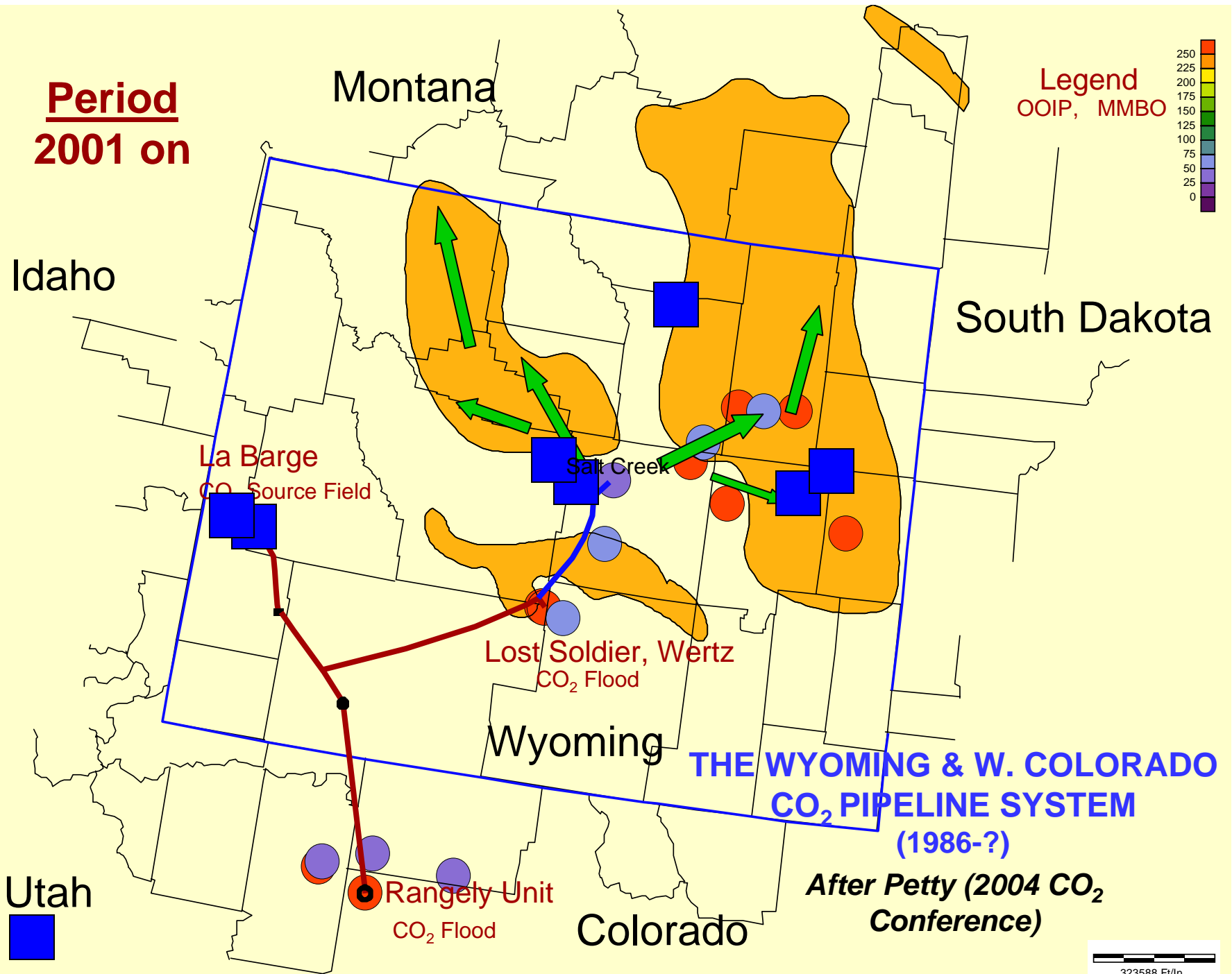
Utah

Rangely Unit
CO₂ Flood

Colorado

*After Petty (2004 CO₂
Conference)*

323588 Ft/in



EXAMPLE NETWORKS (*PLANNED*)

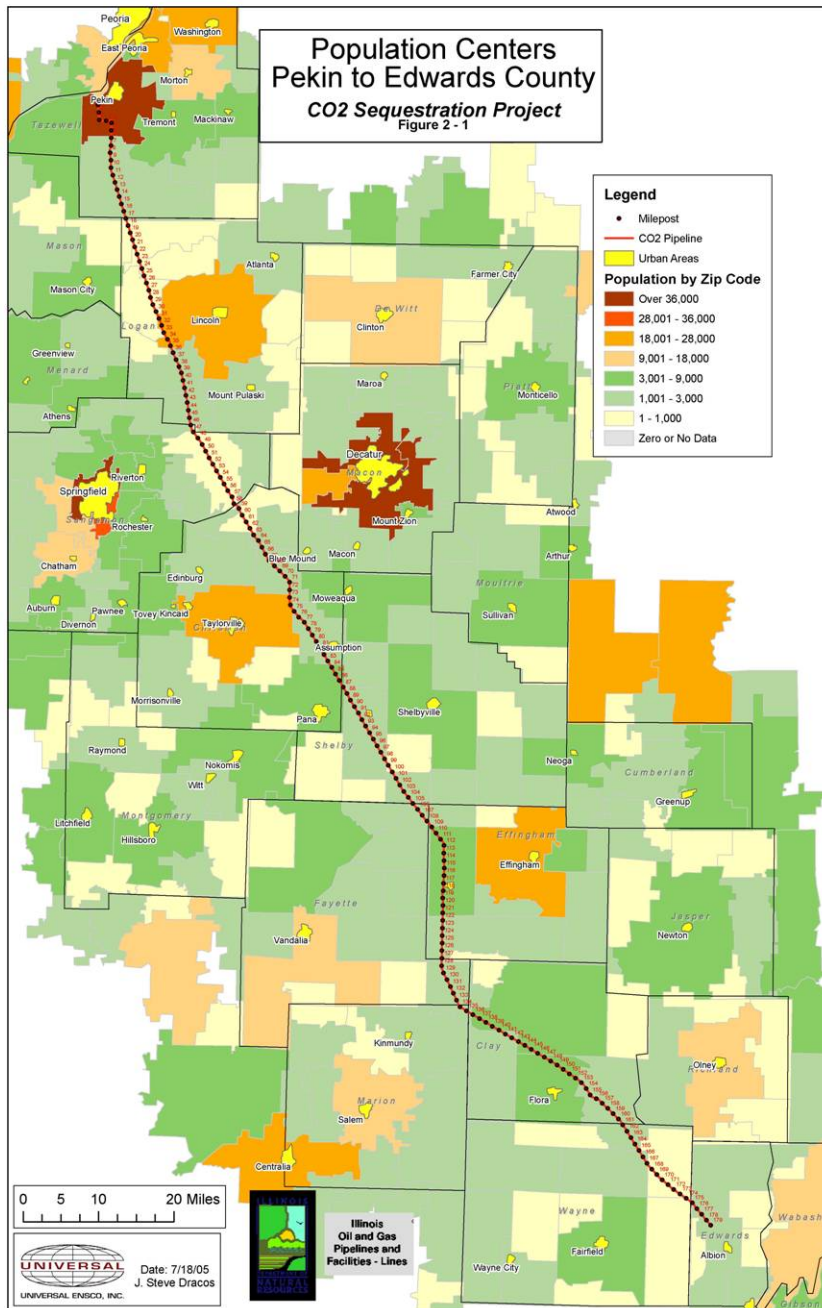
Kinder Morgan's Proposed Sasquatch CO₂ Pipeline; Alberta, Canada

Map Here

Re: KM Personal Communication - 2007

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Illinois Example



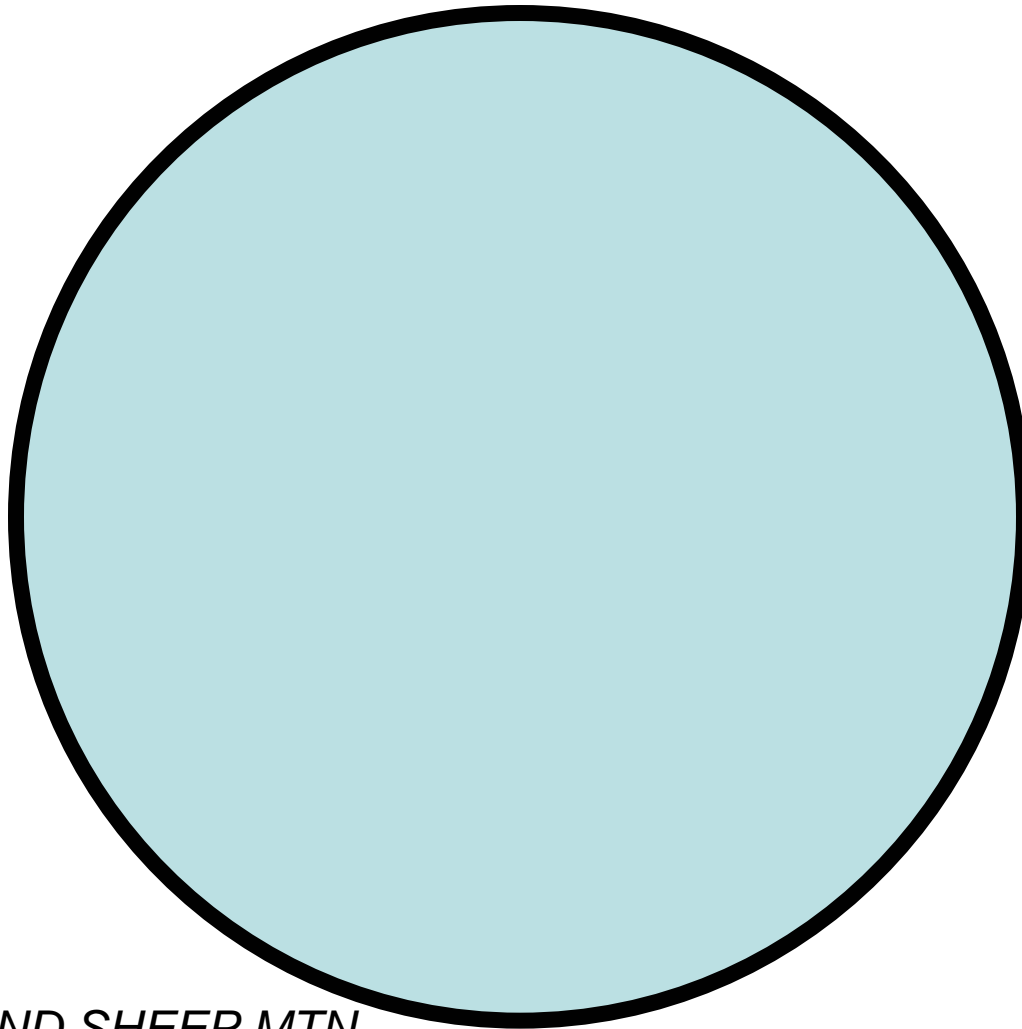
- 180 mile pipeline
- 365 MMscf/d (7.7 million tonnes/yr) designed pipeline from a “CO₂ EOR” perspective
- Medium pressure (2,300 psig) 18-inch pipe, cost estimate is \$779,444/mile
- \$144 million installed

Ref: Illinois Geological Survey - 2007

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Ownership, Point-to-Point, and Open Access Issues

INDIVIDUAL or COMMON OWNERSHIP



CAPACITIES
CONTRACTED BY
PL OWNER(s)/
OPERATOR

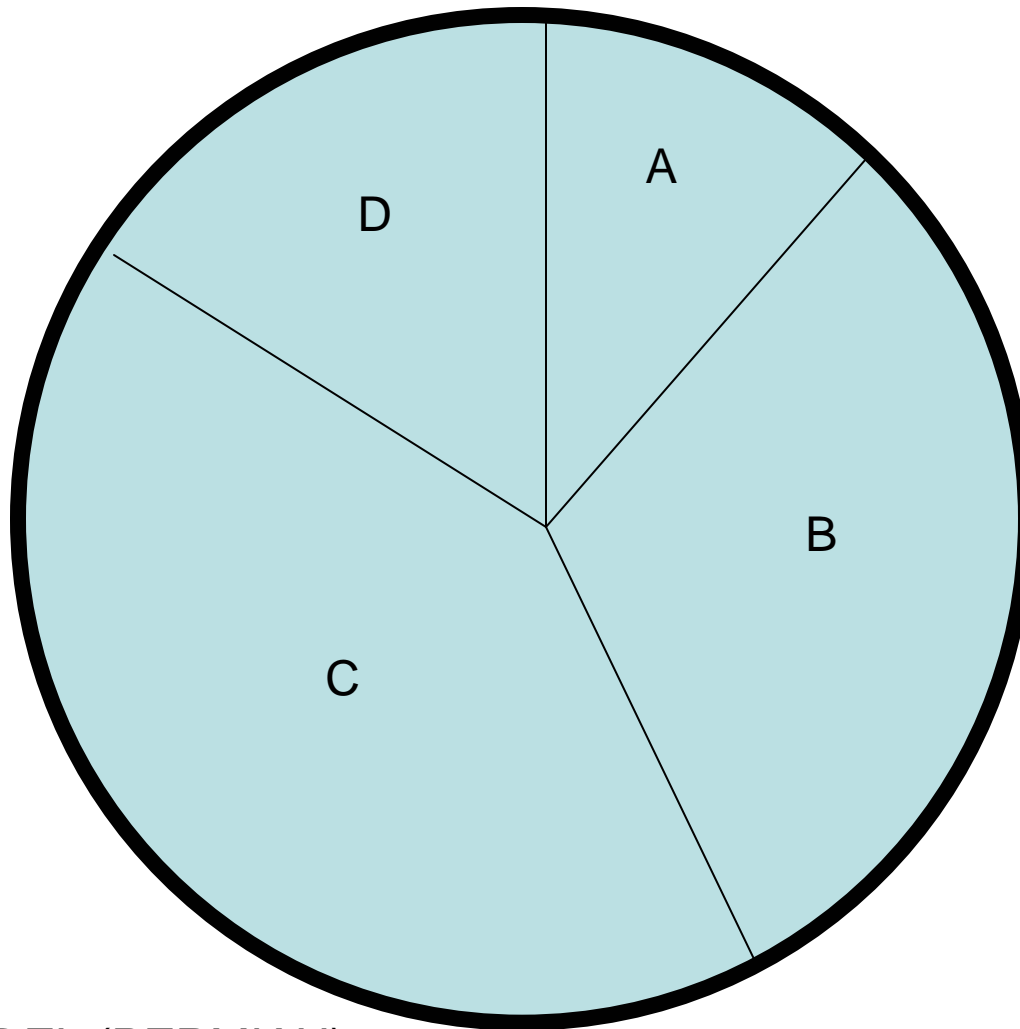
COMMON TARIFFs
FOR EACH
TRANSPORTER

PRIVATE
PIPELINE, NO
OPEN ACCESS

*BRAVO AND SHEEP MTN
MODELS (PERMIAN)*

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DIVIDED OWNERSHIP (a)



CAPACITIES
CONTRACTED
BY EACH
OWNER

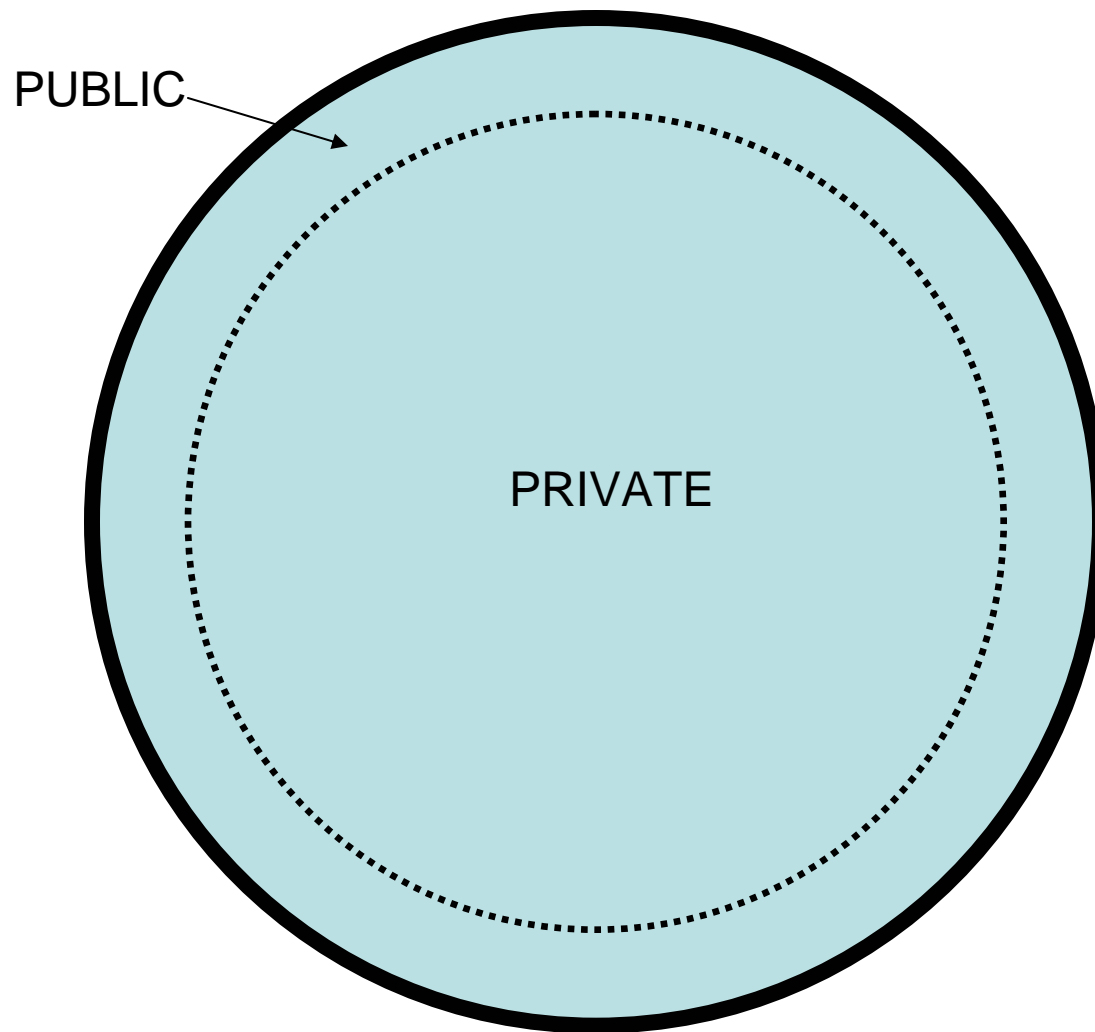
SEPARATE
TARIFFs FOR
EACH OWNER

PRIVATE
PIPELINE, NO
OPEN ACCESS

ESTE MODEL (PERMIAN)

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DIVIDED OWNERSHIP (b)



CAPACITIES
CONTRACTED
BY EACH
OWNER

SEPARATE
TARIFFs FOR
EACH OWNER

FOR PRIVATE
PORTION, NO
OPEN ACCESS

ACCOMODATION
FOR GROWTH

FOR 'PUBLIC'
PORTION, OPEN
ACCESS

ALBERTA MODEL?

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FACILATORS AND ROLES

- INDUSTRY
 - PAST SOURCE-TO-SINK MODELS DOMINATE
 - BUT EXCEPTIONS DO EXIST
 - SEPARATE PL COMPANIES AS FACILITATORS
 - QUASI-GOVERNMENT
 - WYOMING PIPELINE AUTHORITY MODEL
-
- GOVERNMENT ROLES
 - CAPACITY ENHANCEMENTS (OWNERSHIP)
 - ROW ASSISTANCE
 - EMINENT DOMAIN
 - TRANS TEXAS CORRIDOR MODEL

LIST OF PL FACILITATORS

(FOR **TYPES II AND III** {PARTIAL?})

- KINDER MORGAN
- TRINITY CO₂
- BLUE SOURCE
- EL PASO (CIG)
- PENN WEST
- ENBRIDGE
- SEMPRA

QUESTIONS??